Pacific Northwest NATIONAL LABORATORY

PNNL-30747

Assessment of the 3420 Building Filtered Exhaust Stack Sampling Probe Location

Stack Verification Following Fan and Air Blender Additions

December 2020

Julia E Flaherty
Jeremy P Rishel
Sarah R Suffield
J. Matthew Barnett

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99354

Summary

The Pacific Northwest National Laboratory 3420 Building, which is part of the Physical Sciences Facility, houses radiological capabilities so emissions monitoring must be conducted for potential radionuclides in the exhaust air discharge of the building. The air monitoring system is required to conform to Title 40 of the Code of Federal Regulations Part 61 Subpart H, which in turns requires a sampling probe in the exhaust stream to conform to the criteria of American National Standards Institute/Health Physics Society (ANSI/HPS) N13.1-2011, *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stack and Ducts of Nuclear Facilities*.

To support the air emissions permit for the 3420 Building, stack testing that used computational fluid dynamics (CFD) modeling as the surrogate stack and verification tests of velocity uniformity and flow angle on the retrofitted facility stack was performed. The ANSI/HPS N13.1-2011 criteria for the air monitoring probe location are that the coefficient of variation (COV) of velocity uniformity, gaseous tracer uniformity, and particulate tracer uniformity must be less than or equal to 20%. Furthermore, no point in the sampling location may have a gaseous tracer concentration that varies from the mean concentration by more than 30%. Additionally, the flow angle at the sampling location must not be more than 20 degrees. As reported by Recknagle et al. (2018), CFD modeling of the stack demonstrated that the stack meets the criteria at the probe location.

The velocity uniformity and flow angle results from the 3420 stack verification tests, performed in October 2020, demonstrated that the CFD model results may be used to support the qualification of the stack sampling location. The measured velocity uniformity verification test result was 1.4%COV. This value is well within the uniformity criterion, which is that the velocity uniformity be ≤20%COV. Additionally, this value is well within the criterion that the actual stack measurement must be within 5% of the surrogate stack result of 2.1%COV when all four fans are operating. Additionally, the measured average flow angle at the 3420 stack monitor location was 15.5 degrees. Although this is higher than expected based on the CFD model, the result is ≤20 degrees, so the criterion is met.

Based on these stack verification test results, the reconfigured 3420 Building filtered exhaust stack meets the qualification criteria given in the ANSI/HPS N13.1-2011 standard. Further changes to the system configuration or operating conditions that are outside the bounds described in this and the CFD report (Recknagle et al. 2018) may require both additional tests and analysis to determine compliance with the standard.

Acknowledgments

This work was supported by Project 90015 Task 06FIPPD06 – N13.1 Stack Testing 3420 Rad Chem and Project 98668 Task 06EMEFRA.4 – Emissions and Compliance Studies.

We would like to acknowledge the support of the team of Pacific Northwest National Laboratory Facilities and Infrastructure Operations staff that helped in preparations and execution of these tests. We appreciate Dave Peterson, who performed the flow angle and velocity traverse measurements that are reported in this document, as well as Francisco (Frank) Gonzales, Jr., the radiation protection technician who supported these tests. Additionally, specific project staff included Brian Greenaway, Steve Gourley, and Melinda Newhouse. Data and document review by Ernest Antonio also are acknowledged.

Acronyms and Abbreviations

ANSI	American National Standards Institute
CFD	computational fluid dynamics
CFR	Code of Federal Regulations
cfm	cubic feet per minute
COV	coefficient of variation
DV	hydraulic diameter and mean velocity
HDI	“How Do I…?”
HPS	Health Physics Society
NQA	National Quality Assurance
PNNL	Pacific Northwest National Laboratory
QA	quality assurance
RAES	Radiological Air Emission Sampling

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1.0 Introduction

The Pacific Northwest National Laboratory (PNNL) 3420 Building, which is part of the Physical Sciences Facility (PSF), houses radiological capabilities so emissions monitoring must be conducted for potential radionuclides in the exhaust air discharge of this building. The specific emission unit is the EP-3420-01-S (Washington State Department of Health 2019). The air monitoring system is required to conform to Title 40 of the Code of Federal Regulations Part 61 (40 CFR 61) Subpart H, which in turn requires a sampling probe in the exhaust stream to conform to the criteria of American National Standards Institute/Health Physics Society (ANSI/HPS) N13.1-2011, *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stack and Ducts of Nuclear Facilities*.

Stack verification tests were previously performed and reported by Glissmeyer and Flaherty (2010). However, a fourth fan was added in October 2020 to augment the effluent capability as a result of expanded laboratory needs in the 3420 Building. Additionally, an air blender was added to the stack duct to provide the necessary mixing needed to be in compliance with the stack qualification criteria. These physical changes necessitated a different stack qualification approach that addressed the new stack flow rates and fan geometry and inclusion of the air blender.

This report provides information regarding the stack monitoring system qualification criteria and describes the approach that was taken for this particular stack to use a surrogate stack for full demonstration of qualification criteria, followed by verification tests as allowed by ANSI/HPS N13.1-2011. Verification test results and conclusions regarding stack monitoring system compliance with applicable regulations also are reported.

1.1 Qualification Criteria

The qualification criteria for a stack air monitoring probe location are taken from ANSI/HPS N13.1-2011 and are paraphrased as follows:

1. *Uniform Air Velocity* – It is important that the gas velocity across the stack cross-section where the sample is extracted be fairly uniform. Consequently, the velocity is measured at several points in the stack at the position of the sampling nozzle. The uniformity is expressed as the variability of the measurements about the mean. This is expressed using the coefficient of variation (COV), which is the standard deviation divided by the mean and is expressed as a percentage (X%COV). The lower the COV value, the more uniform the velocity. The acceptance criterion is that the COV of the air velocity must be ≤20% across the sampling plane.
2. *Angular Flow* – Sampling nozzles are typically aligned with the axis of the stack. If the air travels up the stack in cyclonic fashion, the air velocity vector approaching a sampling nozzle could be sufficiently misaligned with the nozzle to impair the extraction of particles. Consequently, the flow angle is measured in the duct at the location of the sampling probe. The average air-velocity angle must not deviate from the axis of the duct by more than 20 degrees.

3. *Uniform Concentration of Tracer Gases* – A uniform contaminant concentration in the sampling plane enables the extraction of samples that represent the true concentration within the duct. The uniformity of the concentration is first tested using a tracer gas to represent gaseous effluents. The fan is a good mixer, so injecting the tracer downstream of the fan provides worst-case results. The acceptance criteria are that 1) the COV of the measured tracer gas concentration is ≤20% across the sampling location and 2) at no point in the sampling location does the concentration vary from the mean by >30%.
4. *Uniform Concentration of Tracer Particles* – The second set of tests addressing contaminant concentration uniformity at the sampling position uses tracer particles large enough to exhibit inertial effects. Tracer particles of 10-µm aerodynamic diameter are used by default unless larger contaminant particles are known to be present in the airstream. The acceptance criterion is that the COV of particle concentration is ≤20% across the sampling location.

Section 5.2.2.2 of the ANSI/HPS N13.1-2011 standard defines additional criteria for applying the results of tests performed on a surrogate stack for the actual building stack. In 2019, the Washington State Department of Health authorized a one-time alternate approval allowing the surrogate stack evaluation to be conducted by computational fluid dynamics (CFD) scale modeling. A summary of the criteria as applicable for the 3420 Building stack follows:

- The surrogate stack and its sampling location must be geometrically similar to the actual 3420 Building Filtered Exhaust Stack.
- The product of the hydraulic diameter and the mean velocity (DV) of the scale model must be within a factor of six of the DV for the actual 3420 Building Filtered Exhaust Stack.
- The Reynolds number for the surrogate and actual stacks both must be >10,000.

The surrogate stack results are considered valid if the following are shown by testing on the actual stack:

- The velocity profile in the actual 3420 Building stack meets the uniformity criterion of 20%COV.
- The velocity uniformity (%COV) values for the surrogate and actual stacks agree to within 5%.
- The flow angle criterion (≤20 degrees) is met on the actual 3420 Building stack.

2.0 Stack Qualification Strategy

The 3420 Building stack (i.e., emission unit EP-3420-01-S) qualification strategy relies on a full suite of stack qualification tests performed *in silico* to serve as the surrogate stack. Verification tests performed on the actual stack are therefore necessary to determine whether the surrogate stack test results are considered valid. As reported in Recknagle et al. (2018), the 3420 Building stack with the additional fan (Fan D) and static air blender was modeled with the CFD model STAR-CCM+ (Siemens 2017) to evaluate the flow angle, velocity uniformity, gaseous tracer uniformity, and particulate tracer uniformity at the stack sampling location. Several operating conditions (varying flow rates and operating fans) were considered to ensure that the expected nominal, high, maximum, and set-back flow rates were captured through modeling. A schematic of the 3420 Building stack is shown in Figure 1.

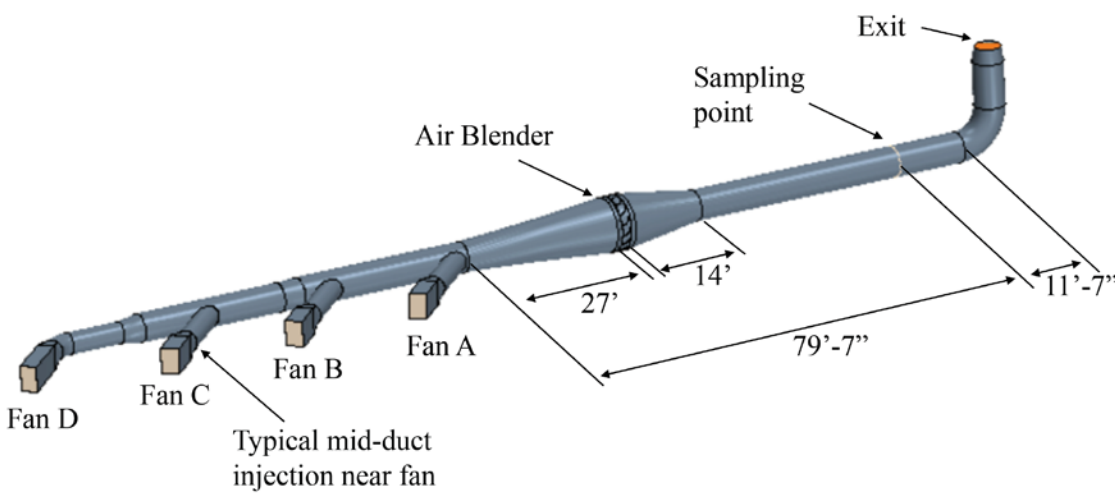

Figure 1. Schematic of the 3420 Building Exhaust System with the Additional Fan (Fan D) and Static Air Blender

Based on the fact that the CFD model was a computational model of the stack at full physical scale, the surrogate CFD model and the actual 3420 Building stack are geometrically similar. This first criterion from Section 5.2.2.2 of ANSI/HPS N13.1-2011 for applying the results from a surrogate stack is therefore met. The remaining criteria rely on calculations of DV and Reynolds numbers. Table 1 shows calculations of the acceptable range of the diameter × velocity criterion that determines the applicability of the surrogate stack (CFD model) results to the actual stack. The product of duct diameter and mean velocity with the approximate normal stack flow rate (~68,700 cubic feet per minute [cfm]; DV = 16,930) was within the acceptable factor of six of the surrogate model's DV product for the nominal flow rate of 80,000 cfm (DV = 19,715) for four operating fans. While Recknagle et al. (2018) reports four-fan operations with approximately 80,000 cfm as a high flow rate, this is the condition that most closely aligns with the current normal flow condition. Table 1 also includes the Reynolds number for the scale tests and the building stack tests. In all cases, the Reynolds numbers are greater than 10,000, which is another criterion for applying the surrogate stack results to the building stack. With this, all three criteria listed in Section 5.2.2.2 of N13.1-2011 for the use of a surrogate stack have been met.

Table 1. Ranges of Acceptable Diameter × Velocity Values and Reynolds Numbers

Stack	Diameter (in.)	Configuration	Mean Velocity (ft/min)	D × V (ft^2/min)	1/6 - 6 (D×V)	Reynolds Number
3420 Stack	62	Four Fans	3,277	16,930	2,822 – 101,580	1.71E+06
CFD Model	62	Four Fans	3,816	19,715	N/A	2.00E+06

2.1 Testing Methods

The testing methods for the verification tests conducted at the 3420 Building stack are described in this section. As described in Chapter 1, only the flow angle and velocity uniformity tests are required on the actual stack to demonstrate the validity of the full suite of surrogate stack results. Tracer testing on the actual stack is not required. Figure 2 is a photograph of the 3420 duct, looking toward the west. Staff on the testing platform (behind the stack, from the perspective in the photograph) handling a standard pitot tube are visible. The large grey rectangular box affixed to the side of the duct opposite the testing platform is the Radiological Air Emission Sampling (RAES) system, which displays flow rate within the stack. Upstream from the stack sampling location, the section of duct containing the air blender is visible; however, the ducts that connect each of the four fans to the main duct are not visible from this perspective.

Figure 2. Photograph of the 3420 Building Exhaust Stack System

Figure 3 shows the portion of the duct where the air blender is installed to provide a perspective for the duct expansion upstream and reduction downstream of the air blender. The air blender is located within the matte grey section of duct.

Figure 3. Photograph of Duct of the 3420 Building Exhaust System with Air Blender Installed (matte grey section with a support stanchion)

PNNL Air Balance staff performed the velocity uniformity measurements following PNNL procedure EPRP-AIR-016, Rev 7. The procedure follows the guidance provided in 40 CFR 60, Appendix A, Method 1. The PNNL procedure requires the use of standard pitot tube, manometer (or magnehelic gauge), and calibrated temperature gauge to measure the pressure within the stack at 10 discrete measurement points across the stack diameter. Two duct diameter traverses, 90 degrees apart, were measured through a side port and a top port in the duct. The pressure values were converted to velocity values based on equations provided in 40 CFR 60, Appendix A, Method 2, to compute the velocity uniformity across the stack cross section.

PNNL Air Balance staff also performed the flow angle measurements following PNNL procedure EPRP-AIR-017, Rev 7. For this procedure, a Type-S pitot tube is used with an angle meter and a manometer (or magnehelic gauge). The angle of the stack flow was measured at 10 discrete measurement points across one of the two stack diameters (through the side port). These flow angle values were used directly to compute the average flow angle across the stack diameter. Figure 4 is a photograph of staff working on the platform to perform traverse measurements, while Figure 5 is a schematic that illustrates the positions of the 10 discrete measurement points used for the velocity uniformity and flow angle measurements.

Figure 4. Photo of Staff Preparing for Traverse Measurements at the 3420 Stack Sampling Location.

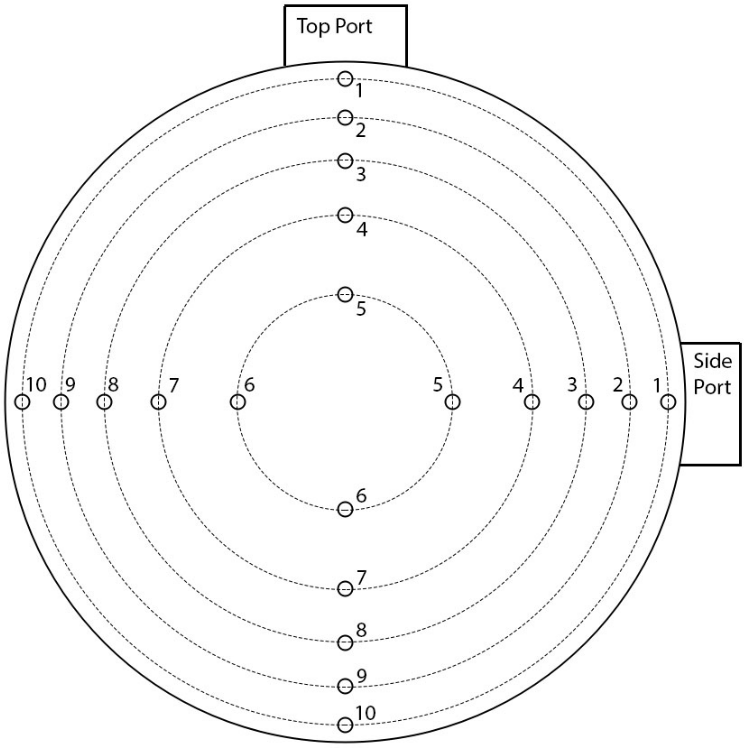

Figure 5. Cross-Section of the Duct at the Test Port with Measurement Points

2.2 Quality Assurance Approach

The PNNL Quality Assurance (QA) Program is based on the requirements as defined in the U.S. Department of Energy Order 414.1C, Quality Assurance, and 10 CFR 830, Energy/Nuclear Safety Management, Subpart A – Quality Assurance Requirements (a.k.a., the Quality Rule). PNNL has chosen to implement the following consensus standards in a graded approach for this work:

- American Society of Mechanical Engineers National Quality Assurance (NQA)-1-2000, Quality Assurance Requirements for Nuclear Facility Applications, Part 1, Requirements for Quality Assurance Programs for Nuclear Facilities.
- American Society of Mechanical Engineers NQA-1-2000, Part IV, Subpart 4.2, Graded Approach Application of Quality Assurance Requirements for Research and Development.

The procedures necessary to implement the requirements are documented in PNNL's standards-based management system called "How Do I…" (HDI).[1]

The PNNL Effluent Management group follows a documented Quality Assurance Plan (Ballinger and Beus 2016) that outlines more detailed elements of this QA approach. Additionally, the use of spreadsheets to calculate quantities that are reported in this document have followed the *Spreadsheet Utility Calculations* procedure (EPRP-ADMIN-014) developed by the PNNL Effluent Management group.

[1] HDI is a web-based system used at PNNL to manage the delivery of laboratory-level policies, requirements, and procedures.

3.0 Stack Verification Results

Stack verification tests were performed by the PNNL Air Balance staff according to procedures used for collecting velocity uniformity and flow angle measurements as described in Section 2.1. Velocity uniformity tests were conducted with a standard pitot tube, a manometer to measure pressure, and a thermocouple to measure the temperature in the stack. The raw measurements collected by this method were in differential pressure units (inches of water). These measurements were converted to the velocity values needed to compute the velocity uniformity and estimate the mean velocity across the duct cross section.

The air balance procedure specifies 10 measurement points across the diameter of the duct, and two duct traverses, 90 degrees apart, are measured to collect from a total 20 discrete measurement positions. However, the center two-thirds of the stack area, which is used for the velocity uniformity calculation, uses points 3 through 8 of the 10 points total in each traverse. A single test with three replicates of each of the two 90-degree separated traverses was conducted for this stack verification measurement. The result of this test was a velocity uniformity of 1.4%COV.

The air balance procedure used to collect cyclonic flow, or flow angle measurements, specifies 10 measurement points across the diameter of the duct. Because of equipment limitations, only a horizontal traverse was measured for this test, and only one traverse replicate was performed. In this instance, all 10 traverse points were used in the calculation of the mean flow angle across the duct. The result of this test was a mean flow angle of 15.5 degrees. The flow angle and velocity uniformity test results are summarized in Table 2.

Table 2. Velocity Uniformity and Flow Angle Results from the 3420 Building Stack.

Operating Fans	Stack Flow Rate, ft^3/min	Flow Angle, degrees	Velocity Uniformity, %COV
A, B, C, D	68,700	15.5	1.4

Note that the RAES flow reading did not match the test result when the test was first performed. Air Balance staff returned to the 3420 Building stack to perform traverse tests; a new correction factor was input to the RAES (in consultation with the vendor) so that corrected flow rate values are now reported from the unit. At the time of the re-test, there was less than 1% difference between the measured and the RAES exhaust values.

4.0 Conclusions

To support the air emissions permit for the 3420 Building stack, CFD modeling was used for the surrogate stack and verification tests of velocity uniformity and flow angle on the retrofitted facility stack were performed. As was described in Section 1.1, the ANSI/HPS N13.1-2011 criteria for the air monitoring probe location are that velocity uniformity, gaseous tracer uniformity, and particulate tracer uniformity must be less than or equal to 20%COV. Furthermore, no point in the sampling location may have a gaseous tracer concentration that varies from the mean concentration by more than 30%. Additionally, the flow angle at the sampling location must not be more than 20 degrees. The CFD modeling of the stack, as reported by Recknagle et al. (2018) demonstrated that the retrofitted stack meets the criteria at the probe location.

The velocity uniformity and flow angle test results from the surrogate stack are key factors in the applicability of the surrogate stack results to the actual facility stack. Table 3 lists the results of velocity uniformity from the CFD model with three operating fans and also with four operating fans (Recknagle et al. 2018). The results from the conditions with three operating fans are included because although the current normal operating condition uses all four fans, the flow rate more closely matches the fan condition from the CFD model. These results serve to contrast the results from all four fans operating at once with a higher flow rate. The results from the higher flow rate with four fans was just slightly higher than the lower flow rate results from operation of three fans.

Table 3. Velocity Uniformity and Flow Angle Results from the 3420 CFD Model with Both Three and Four Fans in Operation, and Actual Stack Verification Test Results. CFD rows adapted from Recknagle et al. 2018.

Stack	Operating Fans	Stack Flow Rate, ft^3/min	Flow Angle, deg	Velocity Uniformity, %COV
CFD	A, B, C	70,000	5.3	1.62
CFD	A, B, D	70,000	5.1	1.59
CFD	A, C, D	70,000	5.2	1.61
CFD	B, C, D	70,000	1.8	1.58
CFD	A, B, C, D	80,000	6.8	2.08
Actual	A, B, C, D	68,700	15.5	1.4

Broadly, the average velocity uniformity (%COV) results from the CFD model were 1.6%COV for three operating fans and a flow rate of 70,000 cfm. With four operating fans and a flow rate of 80,000 cfm, the velocity uniformity was slightly higher at 2.1%COV. The flow angle results were approximately 5 degrees for the three cases in which the three fans operating included the most downstream fan, Fan A. When Fan A is excluded, the flow angle result was much lower, less than 2 degrees. At the higher flow rate with all four fans operating, the flow angle result was nearly 7 degrees.

The velocity uniformity and flow angle results from the 3420 Building stack verification tests, performed in October 2020 are listed in the last row of Table 3. The measured velocity uniformity verification test result was 1.4%COV. This value is well within the uniformity criterion of ≤20%COV. Additionally, this value is well within the criterion that the actual stack measurement must be within 5% of the surrogate stack result of 2.1%COV when all four fans were operating within the CFD model.

Additionally, the measured average flow angle at the 3420 Building stack monitor location was 15.5 degrees. The RAES manufacturer recommends a distance of at least 10 duct diameter lengths between the air blender and the stack monitor probe. In this case, the distance is only 7 duct diameters. Although the CFD modeling suggested that the flow angle would be nearly 7 degrees at this stack monitor location, the larger flow angle result from the actual stack is potentially influenced by the limited distance. While the 15.5-degree flow angle is higher than anticipated, the result is ≤20 degrees, so the criterion is met.

Based on these stack verification test results, the reconfigured 3420 Building filtered exhaust stack meets the qualification criteria provided in the ANSI/HPS N13.1-2011 standard. Further changes to the system configuration or operating conditions that are outside the bounds described in this and the CFD report (Recknagle et al. 2018) may require additional tests and additional analysis to determine compliance with the standard.

5.0 References

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[2] The standard was reaffirmed in 2011 and is essentially identical to the 1999 version.

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Appendix A – Data Sheets

This appendix contains the data sheets that resulted from the verification tests performed at the stack sampling probe location of the retrofitted 3420 Building stack. Figure A.1 is the completed cyclonic flow datasheet per the EPRP-AIR-017 Rev 7 procedure. The average yaw angle, 15.50 degrees, is calculated near the bottom of the data table.

Cyclonic Flow Datasheet

Date and Time: 10-17-20 8:30 a.m. Traverse Point: EP-3420-01-1

Pitot Type: Type-S Pitot Tube Identification No.: #87 02-2021

Manometer Cal Expiration Date: 1/23/2021 Manometer Type/Code No: #19 01-23-2021

Traverse Point	Distance from Port Entrance (in.)	A Port Traverse (yaw angle)	Traverse Point	Distance from Port Entrance (in.)	B Port Traverse (yaw angle)
1	1.6	25	1	1.6	N/A
2	5.1	22	2	5.1	N/A
3	9.1	18	3	9.1	N/A
4	14.0	17	4	14.0	N/A
5	21.2	19	5	21.2	N/A
6	40.8	16	6	40.8	N/A
7	48.0	12	7	48.0	N/A
8	52.9	12	8	52.9	N/A
9	56.9	12	9	56.9	N/A
10	60.4	2	10	60.4	N/A

# of Traverse Pts	Sum of A	Sum of A & B	Sum of B
10	155	N/A	N/A

Average Yaw Angle	15.50	Acceptable
		Yes

If the Average Yaw Angle is <=20 the traverse location is acceptable

Comments:

Completed by (print and sign): Dave Peterson / [signature] Date: 10-19-20

Effluent Management Review: [signature] Thompson Date: 10/27/2020

Cyclonic Flow Version 1.1
Microsoft Excel for Office 365 MSO (16.0.11929.20760) 64-bit

Figure A.1.The 3420 Stack Cyclonic Flow Datasheet

Figure A.2 is the completed velocity traverse data form that is a result of data collected in the *Stack Velocity Traverse* data sheet completed per the EPR-AIR-016 Rev. 7 procedure. In this case, the procedure collects pressure velocity values, and the data sheet included as these values were converted to velocity values in Figure A.2. The result of this test, 1.4% COV within the center two-thirds of the stack area, is listed at the bottom right of the table near the center of the sheet.

VELOCITY TRAVERSE DATA FORM

Stack	**3420**	Run No.	**VT-1**
Date	**10/17/20**	Fan Configuration	**4 Fans (A, B, C, D)**
Testers	Dave Peterson	Fan Setting	**80 %**
Stack Dia.	62 in.	Stack Temp	73.1 deg F
Stack X-Area	3019.1 in.2	Start/End Time	9:05 / 9:55
Test Port	nearest to probe	Center 2/3 from	5.69 to: 56.31
Distance to disturbance	37 ft	Points in Center 2/3	3 to: 8
Velocity units	ft/min		

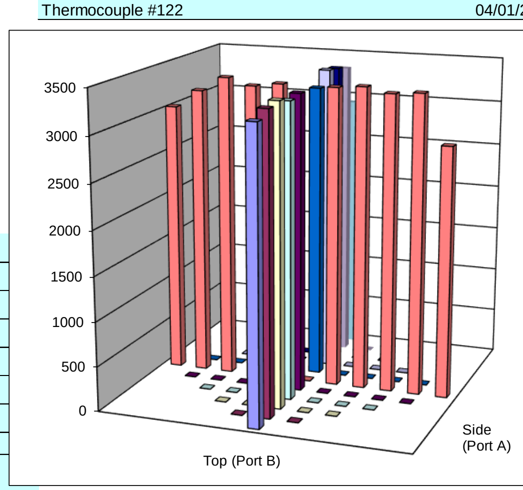
Order -->		1st				2nd			
Traverse-->		Side (Port A)				Top (Port B)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.6	2654	2860	2899	2804.5	3122	3294	3315	3243.7
2	5.1	3291	3366	3394	3350.4	3286	3320	3361	3322.6
3	9.1	3325	3339	3315	3326.7	3373	3337	3347	3352.2
4	14.0	3429	3401	3320	3383.5	3418	3185	3294	3298.8
5	21.2	3325	3403	3347	3358.4	3337	3342	3301	3326.7
6	40.8	3354	3394	3337	3361.7	3315	3223	3315	3284.5
7	48.0	3284	3366	3315	3321.7	3420	3403	3487	3436.8
8	52.9	3425	3389	3378	3397.1	3328	3462	3445	3411.5
9	56.9	3213	3347	3145	3234.7	3356	3339	3411	3368.7
10	60.4	3173	2921	3015	3036.2	3060	2924	2781	2921.5
Averages ---------->		3247.3	3278.7	3246.6	3257.5	3301.5	3282.9	3305.7	3296.7

All	ft/min	Dev. from mean	***Center 2/3***	Side	Top	All
Mean	3277.1		Mean	3358.2	3351.7	3355.0
Min Point	2804.5	-14.4%	Std. Dev.	30.0	61.2	46.1
Max Point	3436.8	4.9%	COV as %	0.9	1.8	**1.4**

Flow	68707	cfm
Vel Avg	3277	fpm

Instuments Used:	Cal Due
Standard Pitot Tube #78	02/01/21
ADM Manometer #26	01/01/21
Thermocouple #122	04/01/21

	Start	Finish	
Stack temp	72.8	73.3	F
Equipment temp	N/A	N/A	F
Ambient temp	59.1	59.5	F
Stack static	1.1	1.1	in H2O
Ambient pressure	29.6	29.6	in Hg
Total Stack pressure	29.68	29.68	in Hg
Ambient humidity	N/A	N/A	RH



Notes: Temperatures from nearby 300A meteorological station. No center point measurements are collected, as it is not required based on procedure.

Entries made by:	Jeremy Rishel / Julia Flaherty	Technical Data Review performed by:	
Signature/date	10/17/2020 / 11/3/2020	Signature/date	Matthew Barnett 11/11/2020

Figure A.2.The 3420 Velocity Uniformity Datasheet

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